New Mexico GEOLOGY
• Science and Service
Volume 11, No. 2, May 1989

Geology and production history of uranium deposits in the Dakota Sandstone, McKinley County, New Mexico

by *William L. Chenoweth*, Consulting Geologist, 707 Brassie Drive, Grand Junction, Colorado 81506

Abstract

The Dakota Sandstone of Late Cretaceous age contains significant uranium deposits in the Gallup–Grants area of McKinley County, New Mexico. U.S. Atomic Energy Commission (AEC) records indicate that, during the period 1952–1970, eleven properties produced 117,815 tons of ore that averaged 0.21% uranium oxide and contained 501,169 pounds of uranium oxide. In addition to the uranium, these ores contained 115,296 pounds of vanadium oxide, which was also purchased by the AEC and/or private companies. Orebodies in the Dakota are found most commonly in carbonaceous, distributary-channel sandstones in the basal part of the formation where the underlying Brushy Basin Member is thin or has been removed by pre-Dakota erosion. A few deposits occur in areas of Tertiary faulting. Uranium-bearing solutions probably entered the Dakota from the uranium-rich Westwater Canyon Member of the Morrison Formation.

Introduction

The southern San Juan Basin of New Mexico is well known for its large resources of uranium that occur in sandstone beds of the Morrison Formation of Late Jurassic age. The Gallup–Grants area of the basin also contains uranium deposits in the Dakota Sandstone of Late Cretaceous age (Fig. 1).

The purpose of this report is to present the most accurate information available concerning ore production from deposits in the Dakota Sandstone and to summarize their geologic setting. Examination of available data indicates that, during the period 1952–1970, eleven properties produced 117,815 tons of ore averaging 0.21% U_3O_8 and containing 501,169 pounds U_3O_8. The oxidized ores in the Dakota Sandstone contained enough vanadium to be of economic importance. A total of 61,602 tons of the uranium ore was analyzed for V_2O_5. These ores contained 115,296 pounds of V_2O_5. Individual shipments ranged from 0.02 to 0.39% V_2O_5, but overall the shipments averaged only 0.09% V_2O_5. Most of the vanadium was purchased by the U.S. Atomic Energy Commission (AEC) under the Domestic Uranium Program Circular 5, Revised. Some vanadium was also purchased by Kerr–McGee Oil Industries, Inc. and the Vanadium Corporation of America.

Because this report deals mainly with historical production data, the reader is referred to reports by Chico (1959), Gabelman (1956), Mirsky (1953), Reimer (1969), and the U.S. Atomic Energy Commission (1959) for details on the geology and ore occurrence. Pierson and Green (1980) have summarized depositional environments of Dakota host rocks, ore controls, and concepts on the source of uranium in the Dakota Sandstone. ☞

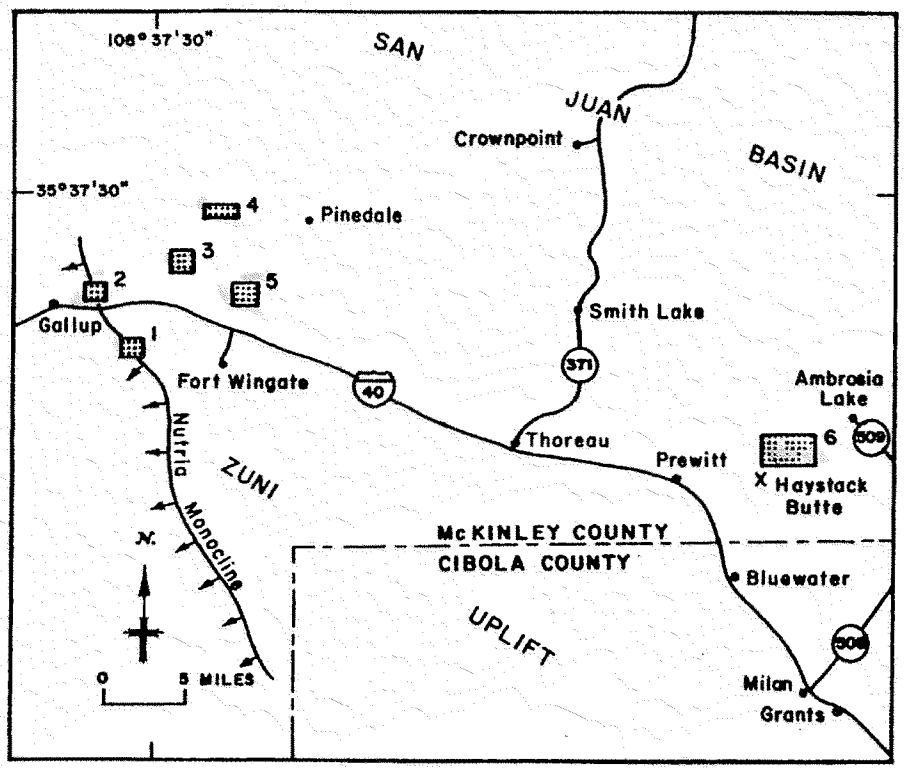

FIGURE 1—Index map of the Gallup–Grants area, New Mexico showing areas where uranium mines and deposits are found in the Dakota Sandstone (stippled); 1, Diamond No. 2 and Eunice Becenti mines; 2, Hogback No. 4 mine; 3, Delter prospect; 4, Churchrock mine; 5, U and Rats Nest mines on Christensen Mesa; 6, Silver Spur, Section 5, and Junior mines.

Also in this issue

Coming

West Potrillo Mounta
beneath and arou
Potrillo basalts
Sugarite Canyon Sta
Oil and gas discover
New Mexico in 198

Information on the Two (2) Becenti Allotments (p. 25)

New Mexico GEOLOGY
Science and Service
Volume 11, No. 2, May 1989

Geology and production history of uranium deposits in the Dakota Sandstone, McKinley County, New Mexico

by *William L. Chenoweth*, Consulting Geologist, 707 Brassie Drive, Grand Junction, Colorado 81506

Abstract

The Dakota Sandstone of Late Cretaceous age contains significant uranium deposits in the Gallup–Grants area of McKinley County, New Mexico. U.S. Atomic Energy Commission (AEC) records indicate that, during the period 1952–1970, eleven properties produced 117,815 tons of ore that averaged 0.21% uranium oxide and contained 501,169 pounds of uranium oxide. In addition to the uranium, these ores contained 115,296 pounds of vanadium oxide, which was also purchased by the AEC and/or private companies. Orebodies in the Dakota are found most commonly in carbonaceous, distributary-channel sandstones in the basal part of the formation where the underlying Brushy Basin Member is thin or has been removed by pre-Dakota erosion. A few deposits occur in areas of Tertiary faulting. Uranium-bearing solutions probably entered the Dakota from the uranium-rich Westwater Canyon Member of the Morrison Formation.

Introduction

The southern San Juan Basin of New Mexico is well known for its large resources of uranium that occur in sandstone beds of the Morrison Formation of Late Jurassic age. The Gallup–Grants area of the basin also contains uranium deposits in the Dakota Sandstone of Late Cretaceous age (Fig. 1).

The purpose of this report is to present the most accurate information available concerning ore production from deposits in the Dakota Sandstone and to summarize their geologic setting. Examination of available data indicates that, during the period 1952–1970, eleven properties produced 117,815 tons of ore averaging 0.21% U_3O_8 and containing 501,169 pounds U_3O_8. The oxidized ores in the Dakota Sandstone contained enough vanadium to be of economic importance. A total of 61,602 tons of the uranium ore was analyzed for V_2O_5. These ores contained 115,296 pounds of V_2O_5. Individual shipments ranged from 0.02 to 0.39% V_2O_5, but overall the shipments averaged only 0.09% V_2O_5. Most of the vanadium was purchased by the U.S. Atomic Energy Commission (AEC) under the Domestic Uranium Program Circular 5, Revised. Some vanadium was also purchased by Kerr-McGee Oil Industries, Inc. and the Vanadium Corporation of America.

Because this report deals mainly with historical production data, the reader is referred to reports by Chico (1959), Gabelman (1956), Mirsky (1953), Reimer (1969), and the U.S. Atomic Energy Commission (1959) for details on the geology and ore occurrence. Pierson and Green (1980) have summarized depositional environments of Dakota host rocks, ore controls, and concepts on the source of uranium in the Dakota Sandstone. ☞

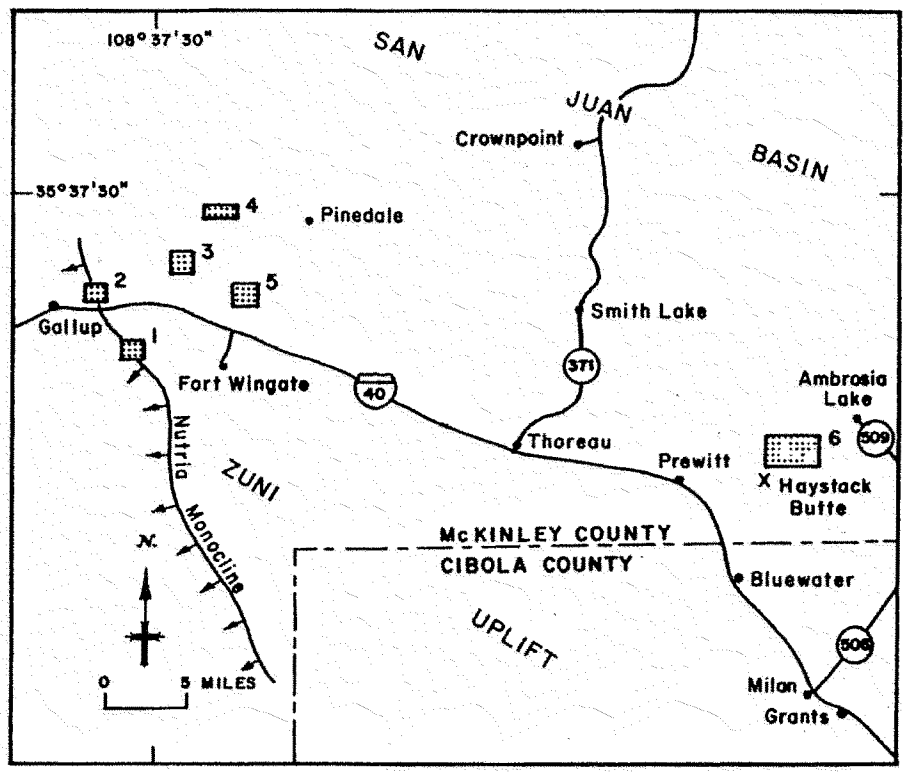

FIGURE 1—Index map of the Gallup–Grants area, New Mexico showing areas where uranium mines and deposits are found in the Dakota Sandstone (stippled); 1, Diamond No. 2 and Eunice Becenti mines; 2, Hogback No. 4 mine; 3, Delter prospect; 4, Churchrock mine; 5, U and Rats Nest mines on Christensen Mesa; 6, Silver Spur, Section 5, and Junior mines.

Also in this issue

Coming soon

West Potrillo Mountains—geology beneath and around the West Potrillo basalts

Sugarite Canyon State Park

Oil and gas discovery wells drilled in New Mexico in 1988

Previous studies

Hilpert (1969, p. 89) noted that nine deposits in the Dakota Sandstone in northwestern New Mexico yielded about 110,000 tons of ore with an average grade of 0.22% U_3O_8 during the period 1952–62. Chenoweth (1977, table 1, p. 260) stated that nine deposits in the Dakota Sandstone in the Grants mineral belt produced 246 tons U_3O_8 (492,000 pounds U_3O_8) during 1951–1970. McLemore (1983) reported 512,917 pounds U_3O_8 produced from the Dakota. The latter two figures were taken from a computer listing of uranium ore production that was generated by the Grand Junction office of the AEC, plus an estimate of the production from the Dakota Sandstone at the Churchrock mine. At the Churchrock mine (Fig. 1) ore was produced from both the Dakota and Morrison Formations. Since this information has been published, more detailed information has been located in the AEC files and is presented here.

Database

Uranium production statistics were routinely compiled for the New Mexico Bureau of Mines and Mineral Resources while I was employed at the Grand Junction office of the U.S. Atomic Energy Commission (AEC) and succeeding agencies, the Energy Research and Development Administration (ERDA), and the Department of Energy (DOE). This report is an outgrowth of that project and summarizes briefly the uranium production from the Dakota Sandstone in the Gallup–Grants area.

A review of notes made by Ingles M. Gay, a mining engineer in the AEC's Grants field office during the 1950's and 1960's, indicated the following discrepancies in the production records: 1) a 1952 shipment labeled Hogback Mountain did not come from the Hogback claims near Gallup (Fig. 1); and 2) a 1952 shipment credited to the Silver Spur mine near Prewitt (Fig. 1) actually came from a nearby mine in the Todilto Limestone Member of the Wanakah Formation. Gay's records were also helpful in determining the time and amount of production from the Dakota at the Churchrock mine.

Records of the AEC ore-buying station at Bluewater indicated the actual amount of production from the Junior mine in the Dakota. In the computer listing this Dakota production is included in production from the Pat mine (in the Morrison Formation) in the same quarter section. Details of these corrections are discussed in the individual mine descriptions.

As the result of this current study, the production from the Dakota Sandstone in the Gallup–Grants area is believed to be 501,169 pounds U_3O_8. The change comes from a review of information on the Churchrock mine.

Stratigraphy and depositional environments of the Dakota Sandstone

In west-central New Mexico, the informal name "main body of the Dakota Sandstone" has been applied to that part of the formation occurring below the Whitewater Arroyo Tongue of the Mancos Shale (Landis et al., 1973).

It is within this unit that the uranium deposits of the Gallup–Grants area occur. The main body of the Dakota Sandstone in this area ranges in thickness from 70 to 180 ft and generally is separated into two parts. The lower part, which was probably deposited in a delta-plain environment, consists of interbeds of crossbedded, fine- to coarse-grained or locally conglomeratic sandstone of the distributary channel and levee; silty, carbonaceous sandstone of the crevasse splay; sandy, carbonaceous siltstone of the well-drained swamp; and clayey siltstone, lignite, and coal of the poorly drained swamp environment. The upper part consists of thick-bedded to massive, fine- to medium-grained, beach or barrier-island sandstone. The lower part usually constitutes from one-third to one-half, and the upper part from one-half to two-thirds of the total thickness of the main body (Pierson and Green, 1980).

Pre-Dakota erosion has produced an important unconformity at the base of the Dakota. In the Gallup area, all of the Brushy Basin Member and part of the Westwater Canyon Member of the Morrison Formation have been removed by pre-Dakota erosion. Thus, basal Dakota uranium host rocks lie in direct contact with uranium-bearing fluvial sandstone units of the underlying Westwater Canyon Member of the Morrison Formation.

Exploration

Soon after the discovery of economic uranium deposits in the Todilto Limestone near Haystack Butte (Fig. 1) in 1950 and in sandstones of the Morrison Formation in the nearby Poison Canyon area in 1951, surface and airborne prospecting spread westward toward Gallup.

Discoveries were made in the Dakota Sandstone in the Nutria monocline (Gallup Hogback) in early 1952 and in the Haystack Butte area at about the same time. Other discoveries were made the following year on Christensen Mesa, east of Gallup. By 1955 all known outcropping occurrences had been found and were being explored. Deposits in the subsurface in the Churchrock area were located in 1957 by extensive drilling programs in the Pinedale area (Fig. 1).

Marketing

In response to development of the uranium mines in the Shiprock and Grants areas of northwestern New Mexico, the AEC established ore-buying stations near those two settlements in early 1952. The station at Shiprock opened on January 17, 1952, and the one near Bluewater opened on June 8, 1952. These stations purchased ore under the terms of the Domestic Uranium Program Circular No. 5, Revised, which included payment for vanadium oxide in "carnotite type" ores. The minimum grade of ore purchased by the AEC was 0.10% U_3O_8. A third ore-buying station was established at Milan, New Mexico in July 1956 to provide a market for the ores being produced in the Ambrosia Lake area. The Bluewater station ceased to pay for vanadium after January 1, 1956, and the Milan station ceased payments for vanadium on July 1, 1957 because most of the ore from the Grants area had been determined not to be the "carnotite type." However, the oxidized ores in the Dakota contained significant vanadium, so mine operators constantly changed their delivery point to the nearest station that paid for vanadium.

The Bluewater station closed in March 1958, Shiprock in June 1958, and Milan in September 1958. The AEC then sold stockpiled ore to nearby mills operated by private companies. Only the mill operated by Kerr–McGee Oil Industries, Inc. at Shiprock recovered vanadium. In 1963 this plant was acquired by the Vanadium Corporation of America.

After the AEC buying stations closed, mill operators were required to pay at least Circular 5, Revised prices, premiums, and allowances for purchased ores (Albrethsen and McGinley, 1982). This policy was in effect until March 31, 1962. After that date, mill operators were required to pay "reasonable" prices for purchased ores (Albrethsen and McGinley, 1982). In most cases the prices paid were less than Circular 5, Revised prices, but lower grade material, less than 0.10% U_3O_8, was accepted. Only the mill at Shiprock continued to pay for vanadium, and when it closed in May 1968, there was no longer a market in New Mexico for vanadiferous ores.

New Mexico GEOLOGY

• Science and Service
Volume 11, No. 2, May 1989
Editor: Carol A. Hjellming
Drafting assistance: Michael Wooldridge
Published quarterly by
New Mexico Bureau of Mines and Mineral Resources
a division of New Mexico Institute of Mining & Technology

BOARD OF REGENTS
Ex Officio
Garrey Carruthers, *Governor of New Mexico*
Alan Morgan, *Superintendent of Public Instruction*
Appointed
Lenton Malry, *Pres.*, 1985–1991, *Albuquerque*
Robert O. Anderson, *Sec./Treas.*, 1987–1993, *Roswell*
Lt. Gen. Leo Marquez, 1989–1995, *Albuquerque*
Carol A. Rymer, M.D. 1989–1995, *Albuquerque*
Steve Torres, 1967–1991, *Albuquerque*
New Mexico Institute of Mining & Technology
President . . . . . Laurence H. Lattman
New Mexico Bureau of Mines & Mineral Resources
Director . . . . . Frank E. Kottlowski
Associate Director . . . . . James M. Robertson

Subscriptions: Issued quarterly, February, May, August, November; subscription price $6.00/calendar year.

Editorial matter: Articles submitted for publication should be in the editor's hands a minimum of five (5) months before date of publication (February, May, August, or November) and should be no longer than 20 typewritten, double-spaced pages. All scientific papers will be reviewed by at least two people in the appropriate field of study. Address inquiries to Carol A. Hjellming, Editor of *New Mexico Geology*, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801

Circulation: 1,600
Printer: University of New Mexico Printing Plant

Production history

Production began in early 1952 and with the exception of 1962–63 continued until the summer of 1970 (Table 1). The following sections summarize the geologic setting of each mine or deposit as well as its production history. Table 2 on page 26 lists production by individual property, years in which the property was operated, and by whom.

Diamond No. 2 mine

The portal of the Diamond No. 2 mine is located in the NW¼NE¼ sec. 33, T15N, R17W. This mine produced ore from three properties: 1) the Mike Smith lease, 2) the Largo Nos. 1 and 2 claims, and 3) the Naomi Becenti lease (Fig. 2). The mine is located on the Gallup Hogback where the beds strike N35°W and dip 28° southwestward in the Nutria monocline. The Diamond No. 2 mine is the largest mine in the Dakota Sandstone in New Mexico. Three major orebodies were mined, each approximately 100 ft wide, 250 ft long, and 4½ ft thick. Ore grades and thicknesses were erratic within each orebody, but each was elongated roughly parallel to the strike of the beds. The uranium is hosted by medium- to coarse-grained, carbonaceous, distributary-channel sandstones in the base of the Dakota. This unit is about 18 ft thick and fills a scour in the Westwater Canyon Member of the Morrison Formation. The channel sandstones are overlain by a lenticular, lignitic, carbonaceous shale unit about 4 ft thick, which represents a poorly drained swamp environment. The ore-bearing sandstones contain numerous mudstone lenses and much carbonized vegetal debris. Ore minerals, including uraninite, possibly coffinite, metatyuyamunite, probably tyuyamunite and carnotite, corvusite, limonite, jarosite, and some marcasite are all associated with carbonaceous debris (Hilpert, 1969). The ore is mostly oxidized above the 450-ft level (Chico, 1959).

Mike Smith lease and the Largo Nos. 1 and 2 claims—The property known as the Mike Smith lease is fee land in the N½NE ¼ sec. 33, T15N, R17W. The 80-acre tract was patented to Esda Alts–Issigi on June 5, 1911 as Patent No. 203103. This Navajo Indian claimed ownership to the land under the 1848 Treaty of Guadalupe Hidalgo, which specified that the United States was to respect the Spanish land grants in the territory the United States won from Mexico. The N½NW¼ sec. 33 is public domain where the Largo Nos. 1–6 claims were staked. Ore production records of the AEC do not divide production between the two properties, so their production statistics are combined.

In late 1952, recorded in some AEC records as 1951, Albert Smith made a 12-ton shipment to the AEC ore-buying station at Bluewater (Fig. 1) that averaged 0.10% U_3O_8 and 0.08% V_2O_5. This shipment was identified as production from the Hogback Mountain mine. Notes in the AEC files from the Grants field office indicate that this shipment probably came from surface exposures on the Mike Smith fee land.

The heirs of Esda Alts–Issigi were Mike Smith, Sr., and his wife, Natanbah Cowboy and his wife, and Johanna Hasheltsie and her husband. On March 3, 1953 these Navajos leased the N½NE¼ sec. 33 to Adee Dodge Enterprises of Santa Fe, New Mexico.

A 28° decline bearing S45°W was started on the ore-bearing outcrop. This coincided with the dip of beds on this portion of the Gallup Hogback. The first ore was sold at the Bluewater ore-buying station in April 1953. Mining levels were established at depths of 13, 21, 35, 50, and 88 ft off the decline as additional ore was located by drilling downdip from the outcrop. On July 15, 1953 Adee Dodge Enterprises became known as the General Uranium Mining Corporation. Mining continued until May 1954 when the Diamond No. 2 mine closed. During the year Dodge and General Uranium operated the mine, they produced 3,014 tons of ore that averaged 0.18% U_3O_8 and 0.10% V_2O_5. This ore was shipped to Bluewater.

During 1954, General Uranium Mining Corporation became the Largo Uranium Corporation with headquarters in Albuquerque, New Mexico. Largo Uranium staked the Largo Nos. 1–6 claims in the N½NW¼ sec. 33.

Largo Uranium, including the Diamond No. 2 mine, was acquired by Four Corners Uranium Corporation of Denver, Colorado in May 1955. Four Corners began operating the Diamond No. 2 mine under the name of Largo Uranium Corporation, which was a subsidiary. One of the first activities of the new operator was to deepen the decline. In August it was at the 400-ft depth with mining levels cut at 200 and 300 ft. Monthly production was about 200 tons. The marketing point was changed in November 1955 from Bluewater to the AEC ore-buying station at Shiprock. In April 1956, the decline was at a depth of 485 ft with mining levels at 400 and 450 ft. Production was about 1,000 tons per month averaging 0.21% U_3O_8 with most of the ore coming from the Largo No. 1 claim (Fig. 2).

Exploratory drilling located the north orebody in early 1956. The decline was deepened to the 550-ft level, and a haulage drift was started on the 500-ft level to reach the north orebody. In August 1956, the delivery point was changed once again from Shiprock to the AEC ore-buying station at Milan (Fig. 1). By February 1957, the drift on the 500-ft level was out 1,100 ft to the northwest, and mining commenced in the part of the north orebody on the Largo Nos. 1 and 2 claims (Fig. 2). In May 1957, the drift was out 1,400 ft from the bottom of the decline and production was at the rate of about 1,500 tons per month with a grade of 0.24% U_3O_8. Some of this ore was mined from the adjacent Naomi Becenti lease.

In November 1957, the delivery point was changed from Milan back to Shiprock in order to be paid for the vanadium. Because of insufficient economic-grade ore, the Diamond No. 2 mine was closed in March 1959. Production had been continuous since June 1955. Ore mined from the Mike Smith lease and the Largo Nos. 1 and 2 claims amounted to 37,365 tons averaging 0.22% U_3O_8 and 0.10% V_2O_5. During April, May, and June 1959 an underground longhole drilling project was conducted; no ore of any consequence was found so the mine was stripped of equipment and abandoned. The mine was dry, but considerable water was encountered below the 500-ft level (Chico, 1959).

On May 20, 1964, the A and B Mining Company of Moab, Utah leased the Mike Smith property and on July 10, 1964, they

A & B mine

TABLE 1—Uranium–vanadium production, by year, from the Dakota Sandstone, McKinley County, New Mexico.

Year	Total ore production (tons)	U_3O_8 (%)	U_3O_8 (pounds)	V_2O_5[1] (%)	V_2O_5[1] (pounds)
1952	1,557	0.21	6,537	0.21	6,715
1953	2,935	0.18	10,618	0.09	5,034
1954	1,111	0.17	3,817	0.07	1,589
1955	3,002	0.19	11,330	0.10	6,045
1956	12,600	0.21	52,222	0.08	20,776
1957	21,243	0.24	103,019	0.15	23,138
1958	17,977	0.23	82,663	0.11	38,935
1959	2,754	0.18	9,700	0.09	2,284
1960	28,115	0.21	119,633	—	—
1961	18,358	0.21	70,813	—	—
1962	0	—	0	—	0
1963	0	—	0	—	0
1964	683	0.19	2,646	0.29	3,931
1965	3,522	0.22	15,798	0.10	3,415
1966	2,093	0.19	7,756	0.07	2,754
1967	520	0.18	1,826	0.06	640
1968	52	0.14	149	0.04	40
1969	445	0.12	1,065	—	—
1970	848	0.09	1,577	—	—
Total	117,815	0.21	501,169	0.09	115,296

[1]Grade calculated on the actual amount of ore analyzed for vanadium oxide.
0, no production that year.
Source: U.S. Atomic Energy Commission files, Grand Junction, Colorado office.

obtained a lease on the Largo claims from the Four Corners Oil and Minerals Corporation, previously known as Four Corners Uranium Corporation. All uranium produced after March 31, 1962 had been subject to the AEC's allocation system; allocations (market quotas) were based on ore reserves developed prior to November 14, 1958. A and B applied to the AEC and received allocations for the Mike Smith lease and Largo claims, and the Naomi Becenti lease. These allocations were 825 and 4,440 pounds U_3O_8 per year, respectively. The allocations were based on reserves located and developed by Largo Uranium, which A and B had demonstrated to the AEC remained on the properties. In August 1964, A and B began cleanup mining in the Mike Smith–Largo part of the mine. This phase continued until early 1967. A and B's production was 5,942 tons of ore that averaged 0.21% U_3O_8 and 0.09% V_2O_5. Most of this ore came from pillars between the 500- and 400-ft levels of the mine. All of A and B's production was shipped to the mill at

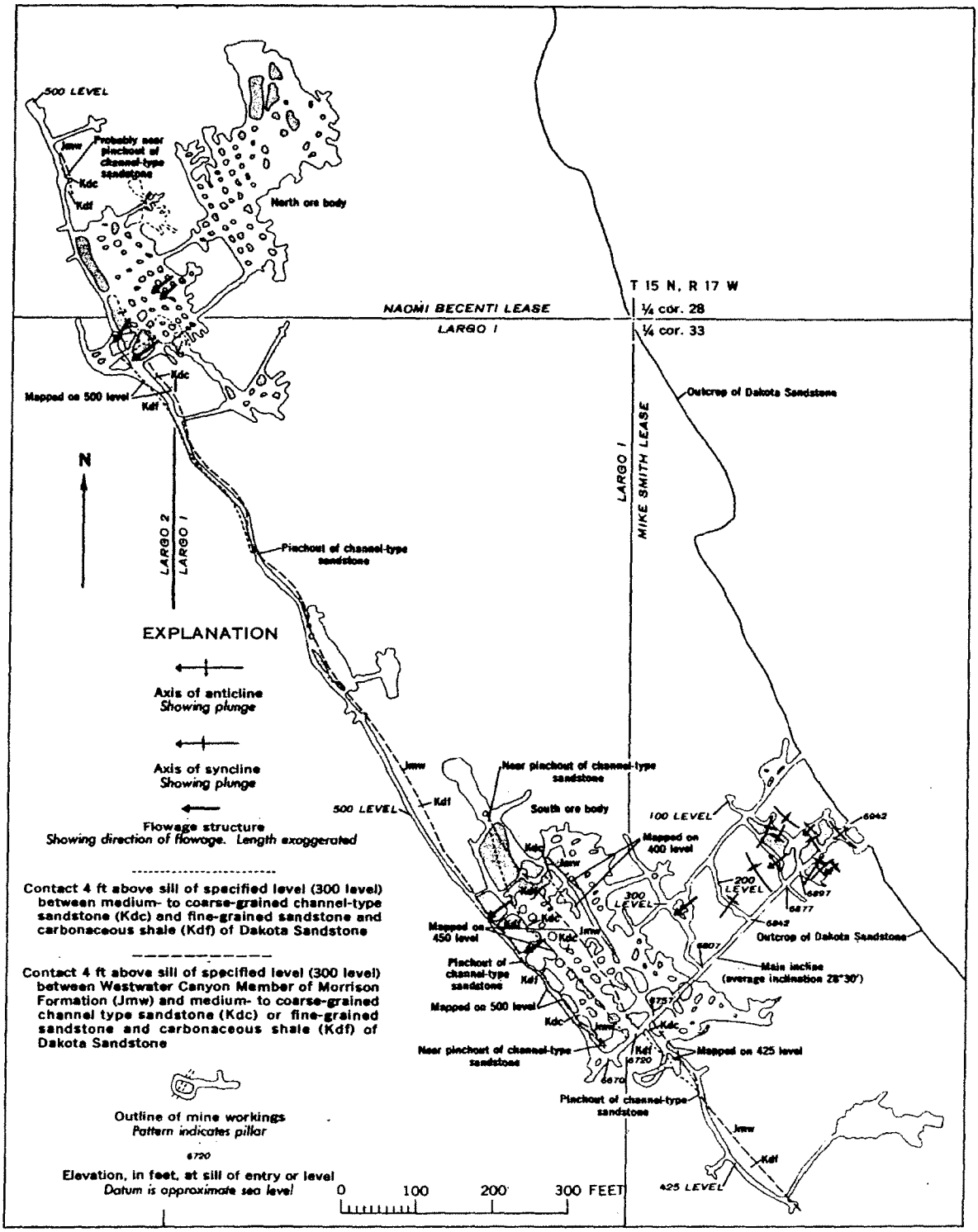

FIGURE 2—Map of the workings of the Diamond No. 2 mine, January 1959 (from Hilpert, 1969, with permission).

Shiprock, which was then operated by the Vanadium Corporation of America.

Shiprock Ltd. of Grand Junction, Colorado obtained a 50% interest in the Mike Smith lease and the Largo claims from A and B Mining Company on June 28, 1967. Shiprock Ltd. began some limited development mining and exploratory drilling to find ore below the 500-ft level. The exploration was not successful and only 848 tons of ore averaging 0.09% U_3O_8 were shipped from the Mike Smith–Largo portion of the mine in 1970. This ore was shipped to the Homestake–Sapin Partners mill near Ambrosia Lake. The Diamond No. 2 mine closed for the last time in the summer of 1970. Total production from the Smith–Largo part from 1952 through 1970 was 47,181 tons averaging 0.21% U_3O_8 and 0.09% V_2O_5 (Table 2).

Naomi Becenti lease—This lease is a Navajo allotment located in the SW¼ sec. 28, T15N, R17W. This allotment was leased by Four Corners Uranium Corporation in late 1955. Drilling on this property by the Largo Uranium Corporation (a Four Corners subsidiary) in February 1956 located the north orebody of the Diamond No. 2 mine. The haulage drift on the 500-ft level of the mine reached the property in mid-1957, and mining commenced later that year. During 1957 through early 1959, Largo Uranium Corporation mined 6,829 tons of ore that averaged 0.26% U_3O_8 and 0.12% V_2O_5. The ore was originally shipped to the AEC ore-buying station at Milan but beginning in November 1958 was shipped to the station at Shiprock.

Four Corners Uranium Corporation subsequently became known as Four Corners Oil and Minerals Corporation. They apparently cancelled their lease on the Becenti allotment in the early 1960's. After A and B Mining Company obtained a new lease in August 1964, they did some cleanup mining, such as pulling pillars from above the bottom level in 1964 and in 1966. Total production by A and B from the Becenti lease was 1,210 tons averaging 0.19% U_3O_8 and 0.15% V_2O_5. This ore was shipped to the Vanadium Corporation of America mill at Shiprock.

Shiprock Ltd. obtained a lease on the Becenti property on June 24, 1967 and did some cleanup mining in 1968 and 1969. Their production, shipped to the Homestake–Sapin Partners mill near Ambrosia Lake, was 497 tons of ore that averaged 0.12% U_3O_8. Total production from the Naomi Becenti lease from 1957 through 1969 was 8,536 tons of ore that averaged 0.25% U_3O_8 and 0.13% V_2O_5 (Table 2).

Eunice Becenti mine

The Eunice Becenti mine is located in the S½NW¼ sec. 28, T15N, R17W. The ore is in the same stratigraphic horizon as at Diamond No. 2 mine immediately to the southeast. Oxidized uranium minerals occur in the upper part of a 10–15-ft, fine- to medium-grained, crossbedded, carbonaceous, distributary-channel sandstone at the base of the Dakota Sandstone. This sandstone rests on the Westwater Canyon Member of the Morrison Formation. Overlying the host sandstone is a 4-ft bed of carbonaceous shale. The beds at the mine dip 31° westward in the Nutria monocline. Gruner et al. (1954) identified meta-autunite, metatyuyamunite, and uranophane from the mine. The deposit was mined from a small open pit with a short decline off the pit wall.

The NW¼ sec. 28 is a Navajo allotment held by Eunice Becenti. Mining rights were assigned to A. W. Tucker, Tom Hyde, and E. D. Davenport on May 12, 1952 by Lease I–149–IND–9294 issued by the Bureau of Indian Affairs. The initial shipment from the property was delivered to the AEC ore-buying station at Shiprock on June 17, 1952. It consisted of 20 tons of ore averaging 0.26% U_3O_8 and 0.13% V_2O_5. In early 1953, the delivery point was changed to the AEC ore-buying station at Bluewater but was changed back to Shiprock in early 1954. With the exception of a 97-ton shipment made in late 1953 by Hagens, Fitzhugh, and Davenport, all shipments made between 1952 and 1954 were by Tucker, Hyde, and Davenport, the original lessors. Production in 1956 and 1958 by A. W. Tucker was shipped to the ore-buying station at Shiprock. Tucker's 1959 production was shipped to the Homestake–New Mexico Partners mill near Ambrosia Lake. Total production from the Eunice Becenti property was 846 tons of ore averaging 0.20% U_3O_8 and 0.14% V_2O_5 (Table 2).

Hogback No. 4 mine

The Hogback No. 4 mine is located in the E½NE¼ sec. 12, T15N, R18W on the Gallup Hogback. Although early production came from claim no. 3 and some of the deeper production was from claim no. 5, most of the ore came from claim no. 4 and hence the name. Uranium at the Hogback property occurs in a 3–5-ft-thick, black, fissile, carbonaceous shale with carbonaceous plant remains. Locally it is nearly peat. The environment of the host rock has been interpreted as being a well-drained swamp (Pierson and Green, 1980). Below the ore-bearing shale is about 35 ft of distributary-channel sandstone, which forms the crest line of the Gallup Hogback. At the Hogback property the beds dip 42° westward in the Nutria monocline.

The Hogback nos. 1–18 claims were located on March 14, 1952 by A. W. Tucker, A. W. Hyde, Tom Hyde, and E. D. Davenport. The initial mining was from an open pit on claim no. 3 on the west side of the Gallup Hogback. Production began in April 1952. After the profitable ore was depleted, the mine was shut in early 1954. By that time, Tucker, A. W. Hyde, and Davenport had mined 1,403 tons of ore that averaged 0.18% U_3O_8 and 0.03% V_2O_5. A few early shipments were made to the AEC ore-buying station at Shiprock, but most of the ore went to the station at Bluewater.

Exploratory drilling during 1955 discovered an extension downdip of the surface ore zone. A. W. Hyde, doing business as Hyde Uranium Company, sank an inclined shaft at the south end of the open pit; by October 1955, the shaft was 155 ft deep and a drift was started at the 150-ft level. After shipping 204 tons of ore that averaged 0.15% U_3O_8 and 0.03% V_2O_5, Hyde shut the mine in January 1956.

Calumet and Hecla, Inc. leased the property in April 1956 and did some exploratory drilling, which indicated additional ore at depth. In 1957, Calumet and Hecla contracted with Bob Mathis of Silver City, New Mexico who deepened the shaft to 285 ft and began a drift to mine the ore. In March 1958, Calumet and Hecla gave Mathis and his brother the lease on the property. The firm had been disappointed with the grade of ore that had been mined. At depth the ore was found to be out of equilibrium; material that would measure 0.17% equivalent U_3O_8 on a gamma-ray instrument would assay only 0.02% U_3O_8 in the laboratory (T. A. Boyden, pers. comm. 1989). Mathis had mined a total of 1,926 tons averaging 0.16% U_3O_8 and 0.03% V_2O_5 for Calumet and Hecla. After Mathis and his brother had mined 937 tons averaging 0.27% U_3O_8 and 0.03% V_2O_5, the Mathis brothers cancelled their lease in the summer of 1958. All the ore mined by Hyde, Calumet and Hecla, and Mathis and Mathis was shipped to the ore-buying station at Shiprock.

In March 1959, the See Tee Mining Company of Grants took over the property but dropped their lease several months later after shipping 1,419 tons of ore that averaged 0.19% U_3O_8.

Winsor Mining Company of Gallup reopened the mine in June 1960 but abandoned it in the fall after shipping 476 tons of ore averaging 0.19% U_3O_8. Both See Tee and Winsor marketed their ore to the Kermac Nuclear Fuels mill at Ambrosia Lake. Total production from the Hogback property was 6,365 tons of ore that averaged 0.19% U_3O_8 and 0.03% V_2O_5 (Table 2). Included in this total were 105 tons of "no pay ore" that averaged 0.05% U_3O_8. The AEC did not pay for material that contained less than 0.10% U_3O_8; shipments that assayed less than that were referred to as "no pay ore."

As mentioned previously on page 23, Albert Smith, in late 1952, shipped 12 tons of ore averaging 0.10% U_3O_8 and 0.08% V_2O_5 to the ore-buying station at Bluewater. The source of the ore was identified as the Hogback Mountain property; therefore, the AEC computer listing of uranium production credited this shipment to the Hogback No. 4 mine. However, notes in the AEC files indicate the shipment came from surface exposures on the Mike Smith lease (Table 1).

Delter prospect

The Delter prospect is located in SE¼NW¼NW¼ sec. 36, T16N, R17W on White Rock Mesa. The NW¼ sec. 36 is a Navajo allotment and the uranium occurrence is undeveloped. Here carnotite occurs in a sandy, carbonaceous shale about 10 ft above the base of the Dakota. The uranium-bearing unit is

part of the fill of a channel cut into the Westwater Canyon Member of the Morrison Formation. The channel is 200 ft wide, 30 ft deep, and trends N30°E into the mesa. The distributary-channel sediments are fine-grained to conglomeratic sandstones with interbedded, black, carbonaceous shales.

U mine

The property known as the U mine is located in the S½ sec. 4, T15N, R16W. The mines are located on the south rim of a Dakota-capped mesa locally called Christensen Mesa. In this area the basal part of the main body of the Dakota Sandstone is about 40 ft thick and is composed of distributary-channel sandstone lenses with interbedded, paludal, carbonaceous shale. Uranium mineralization at the U mine occurs in carbonaceous shale and lignite 15 to 20 ft above the base of the Dakota. The ore zone is about 3 to 5 ft thick. Tyuyamunite has been identified locally where uranium is concentrated (Hilpert, 1969). At Christensen Mesa the Dakota Sandstone rests on the Brushy Basin Member of the Morrison Formation, which is nearly all sandstone because of a facies change.

On April 22, 1953, George Christensen located the Christian 1–20 claims covering the S½ sec. 4. The claims were leased to Williams and Reynolds who began mining on the Christian 16 claim in the E½SW¼ sec. 4 in late 1953. Mining continued until mid-1954 when Williams and Reynolds shut the mine. They shipped a total of 1,302 tons of ore av-

TABLE 2—Uranium–vanadium production, by property, from the Dakota Sandstone, McKinley County, New Mexico.

Property	Period of production	Operator		Ore production (tons)	U_3O_8 (%)	U_3O_8 (pounds)	V_2O_5[1] (%)	V_2O_5[1] (pounds)
Mike Smith lease and Largo Nos. 1 and 2 claims[2]	1952	Albert Smith						
	1953	Adee Dodge Enterprises						
	1953–54	General Uranium Mining Corp.						
	1955–59	Largo Uranium Corp.						
	1964–67	A and B Mining Co.						
	1970	Shiprock Ltd.						
			total	47,181	0.21	202,440	0.09	65,450
N. Becenti lease[2]	1957–59	Largo Uranium Corp.						
	1964, 1966	A and B Mining Co.						
	1968–69	Shiprock Ltd.						
			total	8,536	0.25	42,499	0.13	20,847
E. Becenti mine (Section 28)	1952–54	Tucker, Hyde, Davenport						
	1953	Hagens, Fitzhugh, Davenport						
	1956, 1958–59	A. W. Tucker						
			total	846	0.20	3,350	0.14	2,266
Hogback No. 4 mine (Hogback Nos. 3–5)	1952–54	Tucker, Hyde, Davenport						
	1955–56	Hyde Uranium Co.						
	1957–58	Calumet and Hecla Inc.						
	1958	Mathis and Mathis						
	1959	See Tee Mining Co.						
	1960	Winsor Mining Co.						
			total	6,365	0.19	24,289	0.03	2,934
U mine (Christian Nos. 1–20)	1953–54	Williams and Reynolds						
	1955	Frontier Uranium Co.						
	1957	George Christensen						
	1957	Rem Uranium Co.						
	1958	WCT Engineering Co.						
			total	2,560	0.17	8,460	0.09	4,075
Rats Nest mine (Section 3) (Santa Fe Christensen)	1957	George Christensen						
	1957–58	Rem Uranium Co.						
			total	332	0.28	1,850	0.11	404
Churchrock mine, 489-ft level	1960–61	Phillips Petroleum Corp.						
	1961	Quinta Corp.						
			total	45,997	0.21	188,686	—	—
Silver Spur mines	1952	Charles Davis						
	1952–53	Silver Spur Mining Co.						
	1955–56	Holly Uranium Co.						
	1957–59	Febco Mines						
	1958	Holly Corp.						
	1966	Farris Mines						
			total	5,937	0.25	29,454	0.25	19,202
Section 5 mine	1958	Westvaco Minerals						
			total	23	0.12	54	—	—
Junior mine	1953	Dakota Mining Co.						
			total	38	0.11	87	0.16	118
			TOTAL	117,815	0.21	501,169	0.09	115,296

[1]Grade calculated on the actual amount of ore analyzed for vanadium oxide.
[2]Mined through the Diamond No. 2 decline on the Mike Smith Lease.
(Names in parenthesis are aliases.)
Source: U.S. Atomic Energy Commission files, Grand Junction, Colorado office.

eraging 0.15% U_3O_8 and 0.08% V_2O_5 to the ore-buying station at Bluewater. Frontier Uranium Company leased the property in early 1955 and continued mining until August 1955. Frontier shipped 544 tons of ore averaging 0.20% U_3O_8 and 0.09% V_2O_5 usually to the ore-buying station at Shiprock.

George Christensen began mining in early 1957 on the Christian 9 claim in the N½SE ¼ sec. 4. His shipments to the AEC ore-buying station at Milan continued until mid-1957 and totalled 478 tons of ore that averaged 0.16% U_3O_8 and 0.10% V_2O_5. The property was leased to Rem Uranium Company in mid-1957, and that company shipped 107 tons of ore averaging 0.17% U_3O_8 and 0.10% V_2O_5 to Shiprock. W C T Engineering Company leased the property in March 1958 and shipped 129 tons of ore that averaged 0.16% U_3O_8 and 0.09% V_2O_5 to Shiprock. This ore came from both claims 9 and 16. When mining ceased in mid-1958, a total of 2,560 tons of ore averaging 0.17% U_3O_8 and 0.09% V_2O_5 had been produced (Table 2). There are approximately 1,000 ft of underground workings in sec. 4.

Rats Nest mine

The Rats Nest mine, also known as the Santa Fe Christensen lease, is located in the W½SW¼ sec. 3, T15N, R16W on the south rim of Christensen Mesa. The ore occurrence at this property is identical to that at the U mine in the adjacent section to the west. Uranium ore at the Rats Nest occurs in carbonaceous shale and lignite interbedded with distributary-channel sandstones in the basal Dakota.

The mineral rights to sec. 3 are owned by the Santa Fe Pacific Railroad Company. The south half of the section was leased to Dan Christensen on March 16, 1957 as Santa Fe Pacific Lease No. 9581. In April 1957, George Christensen shipped nine tons of ore that averaged 0.10% U_3O_8 to the AEC ore-buying station at Milan. On April 15, 1957, the property was subleased to Darrell D. Rollins and A. D. Moore, doing business as Rem Uranium Company. This sublease was approved by the railroad on July 19, 1957. Rem began mining from an adit on the mesa rim and commenced shipments to Milan and later to Shiprock. When production ceased in February 1958, a total of 332 tons of ore that averaged 0.28% U_3O_8 and 0.11% V_2O_5 was shipped from the Rats Nest mine (Table 2). Included in this total were eight tons of "no pay ore" that averaged 0.09% U_3O_8.

Churchrock mine

The shaft of the Churchrock mine is located in the SE¼NW¼NE¼ sec. 17, T16N, R16W. Ore deposits in the Dakota Sandstone at the Churchrock mine occur in a distributary sandstone channel that is scoured into a sandstone bed in the lower part of the Brushy Basin Member of the Morrison Formation. The channel, as interpreted from drill-hole data, appears to trend N70°W. Some ore occurs in the underlying Brushy Basin sandstone, but the thicker, more continuous, higher grade ore is in the Dakota Sandstone. The ore deposits in the Dakota are elongated in a N25°E direction parallel to the nearby Pipeline fault. Subsidiary faults striking N40°E to N60°E cross the ore trend and small pods of ore are controlled by these fractures. The largest ore deposit in the Dakota occurs on the east side of a N25°E-trending fault that crosses the channel. Carbonaceous material in the host rock was observed in the mine workings.

The mineral rights to sec. 17 are owned by the Santa Fe Pacific Railroad Company. The surface rights are controlled by the Navajo tribe. Sec. 17 was leased by the Quinta Corporation on March 27, 1957. Phillips Petroleum Corporation acquired a partial assignment of the section in April 1957 and furnished the money for exploration and development. Surface drilling consisting of approximately 300 holes with a total footage of 308,000 ft discovered significant ore deposits in the NE¼ sec. 17 and in the SE¼ of adjacent sec. 8. The ore in the Dakota Sandstone was limited to sec. 17.

Centennial Development Company, a contractor for Phillips, began to sink a 10-ft-diameter, concrete-lined shaft in August 1959. The shaft encountered the top of the Dakota Sandstone at 380 ft in November 1959. The station for the first level was located at 489 ft to mine the ore in the Dakota. Actual ore production began in March 1960 with ore being hoisted through a 42-inch vent hole while sinking of the shaft continued.

In March 1960, some 2,400 tons of Dakota ore averaging 0.22% U_3O_8 were shipped to the Phillips mill at Ambrosia Lake. This was done to claim the AEC bonus of $35,000 for the first 10,000 pounds U_3O_8 produced from a new discovery. The program, under Domestic Uranium Program Circular 6, expired at midnight March 31, 1960.

Mining of the Dakota ore on the 489-ft level continued during 1960. The host sandstone was highly fractured and hard to manage. Steel sets were used to control the ground but some ore was lost because of caving. A second station was cut at 640 ft and mining of the ore in the upper Westwater Canyon Sandstone began in January 1961. At that time, retreat mining was underway on the Dakota level. The third station in the middle Westwater Canyon was located at 840 ft and the shaft bottomed at 862 ft. The 840-ft level was never mined.

On May 15, 1961, Phillips sold their equity to the Quinta Corporation and Centennial took over as the operator. The 489-ft, or Dakota, level was mined out in November 1961 and all work was concentrated on the 640-ft level; at that time the mine was pumping 1,000 gallons of water per minute. The Churchrock mine was closed on May 10, 1962. The pumps in the Churchrock shaft were shut off on September 18, 1963 and the mine was allowed to flood. In August the headframe and hoist were sold and shipped to Bayard, New Mexico. At that time water in the shaft stood at 150 ft below the collar of the shaft.

Total production during 1960–62 was 77,965 tons of ore averaging 0.19% U_3O_8 and containing 302,608 pounds U_3O_8. Using all available information in the AEC files, I have estimated that production from the 489-ft level during 1960 and 1961 was 45,997 tons of ore that averaged 0.21% U_3O_8 and contained 188,686 pounds U_3O_8 (Table 2). Prior to this study AEC geologists had estimated 90 tons U_3O_8 (180,000 pounds) for the Dakota from the Churchrock mine and that number had been used in an earlier report (Chenoweth, 1977).

The United Nuclear Corporation reopened the Churchrock mine (now known as the Old Churchrock) in 1976. During the period 1976–1982, the firm produced approximately 570,000 pounds U_3O_8 by conventional mining and uranium recovery from mine water. It is impossible to determine how much uranium in the water was contributed from the Dakota Sandstone.

Sec. 16 deposit

An ore deposit in a Dakota Sandstone channel similar to the deposit at the Churchrock mine was found in the NW¼ sec. 16, T16N, R16W just east of the Churchrock mine. The orebody also extended northward into sec. 8.

The mineral rights to sec. 16 are owned by the State of New Mexico. In 1956 Tidewater Oil Company began an extensive drilling program in the Churchrock–Smith Lake area on land leased from the New Mexico and Arizona Land Company and the State of New Mexico. This drilling lasted for nearly two years and located only a marginal orebody in sec. 16 in mid-summer 1957.

The ore in sec. 16 and 8 occurs only in the Dakota Sandstone because only a single drill hole penetrated uranium in the Morrison Formation. Drill-hole logs indicate the channel trends nearly north–south with depth to the orebody between 320 and 480 ft.

Silver Spur mines

The Silver Spur mines, including the Small Stake mine, are located in S½ sec. 31, T14N, R10W just north of Haystack Butte (Fig. 1). In this area the Dakota Sandstone rests on claystone of the Brushy Basin Member of the Morrison Formation. Several small faults are present in and adjacent to sec. 31. The main body of the Dakota is composed of distributary-channel or tidal-flat sandstones with interbedded, paludal, carbonaceous shales. This sequence is overlain by a massive, beach or barrier-island sandstone (Pierson and Green, 1980).

The uranium in the S½SW¼ sec. 31 (Small Stake and Silver Spur) occurs in a fine- to medium-grained carbonaceous sandstone, which may be a tidal-flat deposit. This sandstone is approximately 50 ft above the base of the Dakota. Gruner et al. (1954) identified metatyuyamunite in samples from this property. The uranium in the NW¼SE¼ sec. 31 (Silver Spur Nos. 1 and 5) is associated with carbonaceous debris along bedding planes in fine- to medium-grained, well-sorted sand- ☞

stone of the upper Dakota approximately 90 ft above the base of the formation.

Sec. 31 was patented to the Santa Fe Pacific Railroad Company in 1909 as part of a large land grant given to the railroad by the Federal Government. On January 2, 1946, the section was sold to W. A. Berryhill. The language of the deed was confusing about who controlled the mineral rights; one paragraph in the deed stated that the railroad reserved "all oil, gas, coal, and minerals whatsoever," another paragraph stated that the railroad reserved "all coal, oil, and gas." In the spring of 1952, the courts decided that the minerals, including uranium, belonged to Mr. Berryhill.

Uranium-bearing outcrops were discovered in the upper part of the Dakota Sandstone in the NW¼SE¼ of the section in late 1951. On January 9, 1952, the section was subleased to the Silver Spur Mining Company formed by Duane Berryhill, son of W. A., and Lawrence Elkins. In February and March 1952, Silver Spur shipped 432 tons of ore averaging 0.18% U_3O_8 and 0.21% V_2O_5 to the newly opened ore-buying station at Shiprock. This represented the first uranium ore production from the Dakota Sandstone in the Gallup–Grants area. Mining was halted after an injunction was filed by the Santa Fe Pacific Railroad Company.

After the courts decided in favor of the Berryhills, ore shipments began to the AEC ore-buying station that had opened at Bluewater. Mining continued until January 1953 when the near-surface ore was depleted. Between February 1952 and January 1953, Silver Spur mined a total of 1,305 tons of ore that averaged 0.19% U_3O_8 and 0.22% V_2O_5. This ore apparently came from six small open pits in the NW¼SE¼ of the section (Mirsky, 1953). These shipments were identified as production from the Silver Spur No. 5 mine.

In June 1952, Charles Davis subleased the SW¼ sec. 31 from Silver Spur. On June 19, 1952, he shipped 32 tons of ore averaging 0.14% U_3O_8 and 0.28% V_2O_5 to Bluewater from a small adit in the lower part of the Dakota Sandstone in the S½SW¼. This shipment was identified as production from the Small Stake mine. Davis cancelled his lease in late 1952.

Holly Uranium Company leased the section in late 1954 and began an exploratory drilling program in January 1955. In April 1955, Holly did some rim stripping and began to ship ore to Bluewater. After shipping approximately 214 tons that averaged 0.32% U_3O_8 and 0.29% V_2O_5, Holly turned the property back to the owners in January 1956. Some of the ore was produced from a rim cut in the NW¼SE¼ of the section. Shipments by Holly were identified with the Silver Spur No. 1 mine.

In December 1956, Febco Mines (a partnership of Farris, Elkins, and Burns) took over the lease and started a new underground mine in the S½SW¼ of the section. Shipments by Febco began in January 1957 and continued through May 1959 when mining ceased. Febco's production totaled 4,278 tons of ore that averaged 0.26% U_3O_8 and 0.27% V_2O_5. Shipments were made to the AEC ore-buying station at Milan until early 1958 when the delivery point was changed to the station at Shiprock. The final shipment of 388 tons averaging 0.15% U_3O_8 was made to the Kermac Nuclear Fuels mill at Ambrosia Lake during the summer of 1959. Shipments by Febco were identified with the Silver Spur No. 5 mine.

In the summer of 1958, 81 tons of ore averaging 0.27% U_3O_8 and 0.28% V_2O_5 were delivered to the ore-buying station at Shiprock. The property was identified as the Silver Spur No. 1 mine, and the shipper was listed as the Holly Corporation. This ore was probably shipped by Febco from ore mined previously by Holly, but no details are available.

In December 1966, Farris Mines made the final shipment from sec. 31. It consisted of 27 tons of ore averaging 0.15% U_3O_8 delivered to the Phillips Petroleum mill at Ambrosia Lake. Total production from sec. 31 was 5,937 tons of ore that averaged 0.25% U_3O_8 and 0.25% V_2O_5 (Table 2).

In late 1952, W. A. Greer shipped 19 tons of ore averaging 0.11% U_3O_8 and 0.11% V_2O_5 to the ore-buying station at Bluewater. This production was credited to the Small Stake mine. Notes in the AEC records indicate this shipment actually came from sec. 19, T14N, R11W in the Todilto Limestone.

Sec. 5 mine

The Sec. 5 mine is located in the SE¼NW¼ sec. 5, T13N, R10W. This section is a Santa Fe Pacific Railroad Company section that was leased by Westvaco Minerals in the mid-1950's. Westvaco was a subsidiary of the Food Machinery and Chemical Corporation. In the summer of 1958, a mining contractor, Farris Brothers, drove a short adit into the basal Dakota Sandstone near a fault. A total of 23 tons of ore averaging 0.12% U_3O_8 were shipped to the AEC ore-buying station near Milan (Table 2).

Junior mine

The Junior mine is located in the SW¼SE¼NE¼ sec.4, T13N, R10W. It consists of a small rim cut along a fault that brings the Dakota Sandstone in contact with the Westwater Canyon Member of the Morrison Formation. The uranium ore at the Junior mine occurs in a carbonaceous sandstone in the basal Dakota. The Junior mine is approximately 500 ft west of the portal of the Dakota (Pat) mine in the Westwater Canyon Member.

Early in 1953, a total of 38 tons of ore averaging 0.11% U_3O_8 and 0.16% V_2O_5 was shipped to the AEC ore-buying station at Bluewater by the Dakota Mining Company (Table 2). In the AEC computer listing, the total production for the NE¼ sec. 4 is shown as 5,069 tons of ore averaging 0.12% U_3O_8 and containing 12,645 pounds U_3O_8 with no breakdown between the Junior or Dakota (Pat) mines. Hence, the Junior mine was not included in Chenoweth's 1977 tabulation.

Other mines in the Dakota Sandstone

The only other property in New Mexico to produce uranium ore from the Dakota Sandstone is the Butler Brothers No. 1 mine in Sandoval County. This mine, located approximately 15 mi south of Cuba in the W½NE¼ sec. 23, T19N, R1W, is on a hogback along the west flank of the Nacimiento Mountains. Here, uranium occurs in a 1-ft-thick bed of carbonaceous shale or peat at the base of the Dakota; the bed dips 45° southwestward. This deposit has been described by Gabelman (1956).

During 1954 and 1957, R. W. and V. L. Butler made shipments from this deposit. These totaled 23 tons of ore averaging 0.63% U_3O_8 and 0.12% V_2O_5 and containing 290 pounds U_3O_8 and 56 pounds V_2O_5.

Summary

Most of the uranium deposits in the Dakota Sandstone in the Gallup–Grants area are found in distributary-channel sandstones in the basal part of the Dakota. The exceptions are deposits at one of the Silver Spur mines, which is in a beach or barrier-island sandstone of the upper Dakota, and deposits at the Hogback No. 4 mine, which occur in sandy, paludal shale of the lower Dakota.

In the lower Dakota Sandstone, carbonaceous shale beds interbedded with the permeable sandstone act as aquicludes. At the Silver Spur mine the amount of impermeable shale in the lower Dakota is small, so uranium solutions in the underlying Morrison sandstone were able to reach the upper part of the main body of the Dakota. Caprock at the Silver Spur is the Whitewater Arroyo Tongue of the Mancos Shale. At the Hogback No. 4 the uranium may have entered the sandy shale laterally because the unit below the shale is relatively impermeable.

In the Gallup area, Dakota uranium deposits are associated spatially with the pre-Dakota unconformity where the impermeable mudstones of the underlying Brushy Basin Member of the Morrison Formation were eroded. The organic-rich Dakota host rocks are in contact with uranium-rich sandstones of the Westwater Canyon and Brushy Basin Members. To the east in the Haystack Butte area near Grants, Dakota deposits are associated with Tertiary faulting that could have provided conduits for Morrison ground water to reach Dakota host rocks.

Pierson and Green (1980) speculated about an origin for the deposits in the Dakota Sandstone. According to them, the formation of uranium deposits in the Dakota could be controlled by five main factors: 1) previous existence of a ground-water flow with a stratigraphically upward component; 2) introduction into the Dakota of uranium-bearing solutions derived from oxidation of preexisting Morrison uranium deposits or by leaching of the arkosic sediments that compose the Morrison; 3) sufficient transmissiv-

ity within the Dakota to allow passage of the solutions; 4) presence of an impermeable caprock to contain the solutions, which are thought to have risen stratigraphically during their migration northward toward the San Juan Basin or westward toward the Gallup sag; and 5) availability of organic material in the Dakota to reduce and thereby precipitate the uranium from the rising solutions. The author's observations agree with those of Pierson and Green (1980).

ACKNOWLEDGMENTS—This report would not have been completed without the encouragement of Virginia T. McLemore of the New Mexico Bureau of Mines and Mineral Resources. Thanks are owed to Leo E. Little, Manager of the Grand Junction projects office of the DOE for access to the AEC records stored in the DOE archives at Grand Junction. Raymundo J. Chico provided some details of the early history of the Diamond No. 2 mine. John Gabelman, Charles Pierson, Morris Green, and Orin Anderson reviewed the manuscript; their comments are greatly appreciated.

References

Albrethsen, Holger, Jr., and McGinley, F. E., 1982, Summary history of domestic uranium procurement under U.S. Atomic Energy Commission contracts, final report: U.S. Dept. Energy, Rept. GJBX-220(82), 162 pp.

Chenoweth, W. L., 1977, Uranium in the San Juan Basin—an overview: New Mexico Geological Society, Guidebook to 28th Field Conf., pp. 257–262.

Chico, R. J., 1959, The geology of the uranium–vanadium deposit of the Diamond No. 2 mine, near Gallup, New Mexico: Unpublished M.S. thesis, Univ. Missouri, Rolla, 124 pp.

Gabelman, J. W., 1956, Uranium deposits in paludal black shales, Dakota Sandstone, San Juan Basin, New Mexico; in Page. L. R., Stocking, H. E., and Smith, B. B. (compilers), Contributions to the geology of uranium and thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955: U.S. Geological Survey, Professional Paper 300, pp. 303–319.

Gruner, J. W., Gardiner, Lynn, and Smith, D. K., Jr., 1954, Mineral associations in the uranium deposits of the Colorado Plateau and adjacent regions, interim report: U.S. Atomic Energy Commission, Rept. RME-3092, Technical Information Service, Oak Ridge, Tennessee, 48 pp.

Hilpert, L. S., 1969, Uranium resources of northwestern New Mexico: U.S. Geological Survey, Professional Paper 603, 166 pp.

Landis, E. R., Dane, C. H., and Cobban, W. A., 1973, Stratigraphic terminology of the Dakota Sandstone and Mancos Shale, west-central New Mexico: U.S. Geological Survey, Bulletin 1372-J, pp. J1–J44.

McLemore, V. T., 1983, Uranium industry in New Mexico—history, production, and present status: New Mexico Geology, v. 5, no. 3, pp. 45–51.

Mirsky, Arthur, 1953, Preliminary report on uranium mineralization in the Dakota Sandstone, Zuni uplift, New Mexico: U.S. Atomic Energy Commission, Rept. RME-47, Technical Information Service, Oak Ridge, Tennessee, 21 pp.

Pierson, C. T., and Green, M. W., 1980, Factors that localized uranium deposition in the Dakota Sandstone, Gallup and Ambrosia Lake mining districts, McKinley County, New Mexico: U.S. Geological Survey, Bulletin 1485, 31 pp.

Reimer, L. R., 1969, Stratigraphy, paleohydrology, and uranium deposits of Church Rock quadrangle, McKinley County, New Mexico: Unpublished M.S. thesis, Colorado School of Mines, 254 pp.

U.S. Atomic Energy Commission, 1959, Guidebook to uranium deposits of western United States: U.S. Atomic Energy Commission, Open-file Rept. RME-141, 359 pp.

□

Platinum-group metals in New Mexico

by *Virginia T. McLemore, Robert W. Eveleth, Lynn A. Brandvold,* and *James M. Robertson,*
New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801

Introduction

Platinum-group metals (PGM) consist of six elements: platinum (Pt), palladium (Pd), rhodium (Rh), iridium (Ir), osmium (Os), and ruthenium (Ru); platinum and palladium are the most abundant of the group. The PGM typically occur together as natural alloys (for example, osmiridium—an alloy of osmium and iridium) and to a lesser extent as sulfides and arsenides. All the metals are rare (Table 1) and therefore expensive. PGM are used primarily as catalysts in the automotive, chemical, and petroleum-refining industries (U.S. Bureau of Mines, 1987).

Periodically, the NMBMMR is asked to provide information on the occurrence of PGM in the state. More recently, increasing numbers of investors are being approached by speculators to invest in alleged PGM-mining ventures in New Mexico. *NO PGM DEPOSITS ARE CURRENTLY KNOWN IN NEW MEXICO THAT CONTAIN CONCENTRATIONS RICH ENOUGH AND/OR LARGE ENOUGH TO ECONOMICALLY MINE* (Eveleth and Bieberman, 1984) despite numerous claims to the contrary. It is possible that a small amount of PGM could be recovered from the anode slimes produced from a large porphyry copper deposit such as Chino. For example, the concentrates produced by Inspiration Consolidated Copper in Arizona contained a mathematically calculated 0.0000028 troy oz PGM per ton of ore (Phillips, 1980; Eveleth and Bieberman, 1984). There is no documented production of PGM from New Mexico.

Recently the U.S. Geological Survey (USGS) reprinted a map of reported PGM occurrences in the conterminous United States (Blair et al., 1977). That report lists *UNVERIFIED* PGM occurrences in New Mexico as cited in the literature. Not one of those "occurrences" has been found to actually contain PGM.

The purpose of this report is to briefly summarize and evaluate historical reports of PGM occurrences in New Mexico and to consider possible geologic environments in New Mexico that *might* contain undiscovered PGM.

TABLE 1—Abundance of platinum-group metals in crustal rocks (from Greenwood and Earnshaw, 1984).

Element	Symbol	Atomic no.	Abundance (ppm)
Palladium	Pd	46	0.015
Platinum	Pt	78	0.01
Osmium	Os	76	0.005
Iridium	Ir	77	0.001
Ruthenium	Ru	44	0.0001
Rhodium	Rh	45	0.0001

PGM reported in New Mexico
(Blair et al., 1977)

Tampa mine, Bromide district, Rio Arriba County

The Tampa mine in the northern part of the county is one of the largest mines in the Bromide district with a 400-ft shaft and 800–1000 ft of drifts (Bingler, 1968). Sulfide replacement veins containing chalcopyrite, molybdenite, pyrite, malachite, and some free gold occur in schist and granite gneiss of Precambrian age (Lindgren et al., 1910).

"In the Tampa mine, assays frequently show good values in platinum; this is the only place in New Mexico where this rare metal is actually known to exist" (Jones, 1904a). Subsequently, Jones (1904b, 1908, 1915) and Northrop (1959) reported the Tampa mine as a PGM occurrence. However, Lindgren et al. (1910, p. 132) reported that assays of copper ore from the Tampa mine show *NO DETECTABLE PLATINUM*. In fact, L. C. Graton deliberately visited the Tampa mine with the idea of confirming the presence of platinum as reported previously by Jones. He had samples assayed for platinum, something very rarely requested, by Ledoux & Company, probably the best private laboratory at the time, but no platinum was found (Lindgren et al., 1910, p. 132, footnote a).

Red River district, Taos County

The Red River district, near Red River, consists of numerous mines and prospects ranging from Precambrian ore-bearing quartz veins (copper, tungsten, gold, silver, and other ore minerals) to Tertiary ore-bearing veins and disseminated deposits (molybdenite, galena–sphalerite–chalcopyrite, chalcopyrite, galena–sphalerite, and pyrite–gold veins) to Tertiary–Quaternary placer deposits. Mineral deposits occur in Precambrian granite and metamorphic rocks and Tertiary volcanic and intrusive rocks (Schilling, 1960).

In 1910, Fain (1910, p. 3) stated, "there are also indications of . . . sperrylite ($PtAs_2$) . . ." in the Red River district. Northrop (1959) stated, "I know of no subsequent report of this mineral." PGM have yet to be verified from the Red River district.

Ortiz mine, Old Placers district, Santa Fe County

The Ortiz mine is one of the oldest mines in the district. The mine is located on the Cunningham Gulch volcanic vent and follows an irregular gold–quartz vein as much as 4 ft wide and 1 mi long (Lindgren et al., 1910; Elston, 1967). Most of the mining occurred between 1832 and 1870 although several attempts have been made more recently.

Owen and Cox (1865, p. 15) reported an

☞

NOTES FROM THANE COX

Geology and production history of uranium deposits in the Dakota Sandstone, McKinley County, New Mexico

Grant dist

Diamond # 2
- Mike Smith lease
- Largo No 182
- Naomi Becenti lease

1848 Treaty of Guadalupe Hidalgo
- ~~General Uranium Mine Corp~~

A & B Mine
Churchrock Mine

Hogback No. 4 Mine
Eunice Becenti Mine
Ratler prospect
V, mine

Rats Nest Mine
Sec. 16 deposit
Silver Spur Mines
Sec. 5 mine

Junior Mine
Butler Brother No. 1